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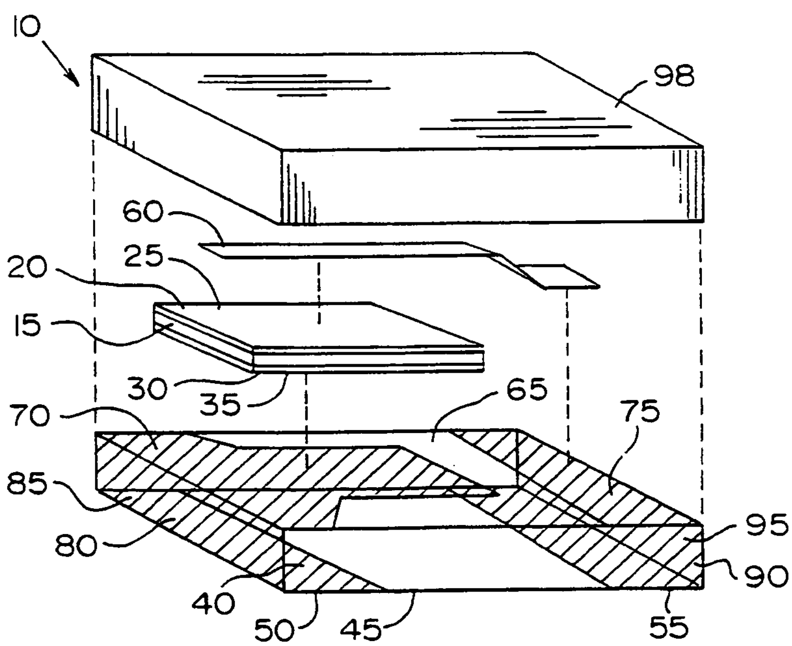
(54) Title: SURFACE MOUNTED THERMISTOR DEVICE



(57) Abstract

A thermistor device (10) is made of a thermistor element (15) having a top conductive coating (25) and a bottom conductive coating (35). The element (15) rests upon a non-conductive carrier substrate (40) having a first external contact (50) and a second external contact (55) compatible for mounting upon a printed circuit board. A conductive connector (60) extends from the top conductive coating (25) to the second external contact (55) while the bottom conductive coating (35) rests upon a second internal contact (75) on the carrier substrate (40). Encapsulation (98) is placed over the thermistor element (15) for a uniform handling surface and to provide protection to the thermistor element (15).

*(Referred to in PCT Gazette No. 30/2000, Section II)

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SURFACE MOUNTED THERMISTOR DEVICE

FIELD OF THE INVENTION

This invention pertains to thermistors and, more particularly, to thermistor constructs that can be handled by pick-and-place apparatus for assembling circuit boards.

BACKGROUND OF THE INVENTION

Thermistors are resistive components that have a temperature coefficient of resistance (as temperature changes, resistance changes). Typical thermistors are two-terminal ceramic semi-conductive parts. Thermistors are made, for example, of various mixtures of oxides of manganese, nickel, cobalt, copper, uranium, iron, zinc, titanium, barium and magnesium. The temperature coefficient is determined by the proportions of oxides in the mixture as is well understood in the art.

Thermistor Chip Construction:

Thermistors are comprised of an electrically resistive ceramic layer of sintered metal oxides. The layer is typically formed by tape casting a ceramic slurry and firing to remove organic binders and densify the ceramic. The ceramic is then covered on opposite faces with a thick film silver bearing conductor composition. The conductor is fired on to provide intimate physical and electrical contact between the conductor metal and the ceramic layer. In the manufacture of chip-style thermistors, large sheets of ceramic material so prepared are diced into smaller units called chips or wafers. The conductor layer forms an electrode contact on opposite faces of the chip. Depending upon the control exercised in the fabrication of the electroded ceramic sheet and dicing of the chips, the distribution of resistance values around the average resistance will fall within a span of about +/-10% of the average value.

The manufacture of traditional "monolithic" or "thick film" surface mount thermistors follows a processing routine very similar to chip, disk or rod thermistors, i.e., casting, pressing or extruding and firing to form a sheet, disk or rod of ceramic, followed by electroding and

dicing of the sheet or rod. In their final, unsorted, untrimmed state, the resistance values of the thermistors are distributed around some average value. This resistance distribution has a range equivalent to approximately +/- 2 degrees centigrade. Obtaining surface mount thermistors with a greater level of precision requires sorting or trimming the parts. Sorting generates high volumes of scrap. Trimming of traditional surface mount thermistors, either with a laser or abrasive method, is a costly and difficult process.

Various techniques for manufacturing thermistors have been proposed as, for example, are disclosed in the following patents: U.S. Patent No. 5,257,003; U.S. Patent No. 4,993,142; U.S. Patent No. 4,786,888; U.S. Patent No. 4,480,376; and U.S. Patent No. 4,434,416.

It is an advantage, according to this invention, to provide an improved thermistor device and a method of making such a thermistor device.

It is yet another advantage to provide a surface mountable thermistor device that is economical to make, has a uniform package size and excellent tolerances.

It is yet another advantage that surface mount thermistors can be provided in resistance values and with resistance temperature response characteristics matching those of conventional wafer-style thermistor products.

SUMMARY OF THE INVENTION

A surface mounted thermistor device is comprised of a thermistor element having a top face with a top conductive coating thereupon and a bottom face with a bottom conductive coating thereupon and further comprised of a carrier substrate made of an electrically insulating material and suitable for mounting upon a printed circuit board. The substrate has a bottom face with a first external contact and a second external contact. The first external contact is in electrical communication with the bottom conductive coating of the element. The second

external contact is in electrical communication with the top conductive coating of the element.

A method of making a surface mounted thermistor device is comprised of the steps of:

a) forming a patterned conductive coating on an insulating carrier substrate such that external and internal electrical contacts are formed;

b) providing electrical continuity between the internal and external electrical contacts;

c) mounting a thermistor chip or disk on an internal electrical contact;

d) providing internal electrical continuity between the thermistor element and the carrier substrate by attaching a conductive wire, tape or coating;

e) optionally trimming the resistance values of the device; and

f) forming an encapsulation over the thermistor element of the device.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an exploded perspective view of a thermistor device in accordance with a first embodiment of the subject invention;

Fig. 2 is an exploded side view of the thermistor device in Fig. 1;

Fig. 3 is a sectional view of a thermistor device in accordance with a second embodiment of the subject invention;

Fig. 4 is a sectional view of the thermistor device in accordance with a third embodiment of the subject invention;

Fig. 5 is a sectional view of the thermistor device in accordance with a fourth embodiment of the subject invention;

Fig. 6 is a sectional view of the thermistor device in accordance with a fifth embodiment of the subject invention; and

Fig. 7 is a sectional view of the thermistor device in accordance with a sixth embodiment of the subject invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

General Description of the Device:

Referring to Figs. 1 and 2, a surface mounted thermistor device 10 is illustrated and comprised of a thermistor element 15 having a top face 20 with a top conductive coating 25 thereupon and a bottom face 30 with a bottom conductive coating 35 thereupon.

A carrier substrate 40 is made of an electrically insulating material. The carrier substrate 40 has a bottom face 45 with a first external contact 50 and a second external contact 55. The first external contact 50 is in electrical communication with the bottom conductive coating 35 of the element 15. The second external contact 55 is in electrical communication with the top conductive coating 25 of the element 15 through a conductive connector 60.

The conductive connector 60 may be comprised of a conductive wire, conductive tape, conductive epoxy, conductive shunt or a conductive coating extending from the top conductive coating 25 to the second external contact 55. The conductive connector 60 may also be a ball of high temperature solder secured to the second external contact 55 and also secured to the top conductive coating 25 with lower temperature solder.

As illustrated in Figs. 1 and 2, the substrate 40 also has a top face 65 with a first internal contact 70 which is electrically connected to the bottom conductive coating 35 of the element 15. The first internal contact 70 may be connected to the bottom conductive coating 35 using conductive adhesive, solder or a mechanical attachment. Furthermore, the first internal contact 70 is electrically connected to the first external contact 50.

Additionally, the top face 65 of the substrate 40 may have a second internal contact 75 which is electrically connected to the conductive connector 60. This connection

may be made using a conductive adhesive, solder or a mechanical attachment. Furthermore, the second internal contact 75 is electrically connected to the second external contact 55.

Again, as illustrated in Figs. 1 and 2, the first internal contact 70 and the first external contact 50 are electrically connected by a first intermediate segment 80 extending around the substrate 40 thereby forming a continuous conductive band 85 from the first internal contact 70 to the first external contact 50. Additionally, the second internal contact 75 and the second external contact 55 are electrically connected by a second intermediate segment 90 extending around the substrate 40 thereby forming a continuous conductive band 95 from the second internal contact 75 to the second external contact 55. Each of these continuous bands 85, 90 may be formed by a conductive wrap around film.

To provide a uniform handling surface and to protect the thermistor element 15, an encapsulation 98 may cover the thermistor element 15 and the associated circuitry on the top face 65 of the substrate 40. The encapsulation 98 may be made of plastic and applied such that it conforms to the contour of the substrate 40 and associated circuitry.

The substrate 40 may be comprised of any number of different non-conductive materials including alumina, PCB, fiberglass reinforced epoxy, fiberglass reinforced polyester, ceramic, polyimide film or glass.

Fig. 3 illustrates a sectional view of a thermistor device 110 in accordance with a second embodiment of the subject invention. Most of the details of the thermistor device 110 illustrated in Fig. 3 are identical to the thermistor device 10 illustrated in the Figs. 1 and 2 and therefore, only those different elements will be discussed. Unlike the embodiment illustrated in Figs. 1 and 2, the carrier substrate 140 has only a first internal contact 170 and does not have a second internal

contact similar to 75 in Figs. 1 and 2. Instead, the second external contact 175 and the top conductive coating 125 are extended until they meet. This can be accomplished by applying a conductive coating after the top conductive coating 125 and second external contact 175 are in place connecting the two contacts.

It should be appreciated from inspection of Fig. 3 that it is entirely possible to include more than one thermistor element on the carrier substrate 140. Thermistor element 115 is placed side by side with thermistor element 117 on the substrate 140 such that the two thermistor elements 115, 117 act in parallel with one another. It should also be appreciated that thermistor element 115 may be placed on top of thermistor element 117 such that the two elements 115, 117 act in series with one another. Different numbers of thermistor elements in parallel or in series may be used upon the substrate 140 and still be within the spirit of the subject invention.

Fig. 4 illustrates a thermistor device 210 in accordance with a third embodiment of the subject invention. Just as before, similar details to that embodiment illustrated in Figs. 1 and 2 will not be discussed but the differences between the two embodiments will be discussed. While in the first embodiment a conductive connector 60 in the form of a conductive band was utilized, Fig. 4 illustrates a conductive connector 260 not in the form of a conductive band but in the form of a conductive coating extending from the top conductive coating 225 of thermistor element 215 to the first internal contact 270 which is electrically connected to the second external contact 275. Unlike in the first embodiment, Fig. 4 illustrates two thermistor elements 215 and 217 mounted upon the carrier substrate 240.

To electrically insulate the conductive connector 260 from the sides of the thermistor element 217 an insulating dam 299 of a non-conductive material, such as a non-conductive epoxy, may be placed withing the cavity 296

between the conductive connector 260 and the edge of the element 217.

Fig. 5 illustrates a thermistor device 310 in accordance with a fourth embodiment of the subject invention. Rather than comparing this device 310 directly to the embodiment illustrated in Figs. 1 and 2, this device 310 will instead be compared with the device 210 illustrated in Fig. 4.

The only difference between device 210 and device 310 in Fig. 5 is the electrical connection associated with the carrier substrate 340. Unlike continuous band 285 comprised of the first external contact 250, first intermediate segment 280 and first internal contact 270, and the continuous band 295 comprised of second external contact 255, second intermediate segment 290 and second external contact 275, the embodiment illustrated in Fig. 5 illustrates a substrate with a first external contact 350 connected to a first internal contact 370 by conductive material 386 extending through a hole 387 in a substrate 340 between contacts 350, 370. Additionally, second external contact 355 and second internal contact 375 are electrically connected by a conductive material 392 extending through a hole 393 in the substrate 340 between the contacts 355, 375. It should be appreciated that these plated through-holes in the substrate 340 may be utilized in any of the other substrate designs illustrated in this application.

Fig. 6 illustrates a cross section of a thermistor device 410 in accordance with a fifth embodiment of the subject invention. Once again this embodiment has the most similarities with the embodiment illustrated in Fig. 4 and, for that reason, will be discussed in conjunction with that embodiment.

Unlike the conductive connector 260 in Fig. 4 comprised of a conductive epoxy, Fig. 6 illustrates an embodiment whereby the second external contact 455 is in electrical communication with second internal contact 475.

Attached to the second internal contact 475 is a connecting conductor 460 comprised of a jumper wire, which is attached to the top conducting coating 425.

Fig. 7 illustrates a cross section of a thermistor device 510 in accordance with a sixth embodiment of the subject invention. This embodiment has the most similarities with that embodiment illustrated in Fig. 6 and for that reason will be discussed in conjunction with that embodiment.

Unlike the conductive connector 460 in Fig. 6 comprised of a jumper wire, Fig. 7 illustrates a thermistor device 510 with a conductive connector 560 comprised of a ball 561 of high temperature solder placed between the top conductive coating 525 of the thermistor element 515 and the second internal contact 575. The ball 561 is electrically connected to the second internal contact 575 with joint 562 of low temperature solder that melts at a lower temperature than the high temperature solder. The ball 561 is electrically connected to the top conductive coating 525 using a wire 563 extending therebetween and secured to the ball 561 with joint 563 of low temperature solder. The wire 563 may be secured to the top conductive coating 525 also using low temperature solder. By including the solder ball 561, installation of the wire 563 for electrical continuity between the top conductive coating 525 and the second internal contact 575 is made much easier.

Throughout this discussion, conductive connectors have been used as individual elements. It is entirely possible to mount conductive connectors, such as that illustrated in Fig. 1, to a printed circuit board and place the board over the thermistor element circuitry, thereby providing the necessary connection between the top conductive coating and the second internal contact.

The device described herein represents an advance in the art of manufacture of surface mount thermistors. The device is constructed from a patterned carrier

substrate and one or more chip of disk style thermally sensitive resistors, commonly known as thermistors. The thermistors have a characteristic temperature dependence of resistance, which is determined by the composition of the metal oxide ceramic core.

The carrier substrate is constructed such that a pattern of conductive material on one surface provides electrical contacts for at least one metalized surface of at least one chip or disk thermistor and a pattern of conductive material on at least one other surface forms the exterior electrical contacts of the finished device. The pattern of conductive material on the carrier substrate is such that electrical continuity is provided between the contacts for the thermistor and the exterior electrical contacts of the device. At least one chip or disk thermistor is mounted on the carrier substrate such that electrical contact is made with part of the conductive pattern on the carrier substrate. A conductive wire, tape or coating is applied to provide electrical continuity within the device and an external encapsulation provides protection of the active elements and a uniform handling surface.

Device Construction:

The device is constructed from a patterned carrier substrate, one or more thermistor elements (chips or disks) and conductive wire, tape or coating and an encapsulation. The carrier substrate may be any insulating material with any conductive coating. Typical carrier substrate materials include fiberglass reinforced epoxy or polyester, ceramic and glass. Typical conductive coatings include copper or nickel plating, thick film silver or conductive adhesives. The conductive material is patterned to provide pads which serve as the external electrical contacts of the device and pads which serve as internal contacts for mounting and electrically connecting the thermistor chip or disk. Continuity is provided between the external contacts and the internal contacts by any of

various methods which include plated through holes, plated edges, filled vias or physically installed conductive jumpers. One thermistor chip or disk, or multiple matched chips are mounted on the internal contact such that one chip surface coated with conductive material is in electrical contact with the mounting pad. The internal continuity of the device is provided by attaching a conductive wire, tape or coating to the opposite surface of the thermistor which is coated with a conductive material and also connecting the conductive wire, tape or coating to another internal contact pad or to another thermistor chip mounted on another internal contact pad.

The thermistor element, which may be a chip or disk, may be used as cut and mounted or may be trimmed for resistance after mounting on the carrier substrate by a laser or abrasive process. The trimming is more easily accomplished than with conventional thick film or monolithic surface mount thermistor devices.

An encapsulation is applied to the finished device which provides protection for the active elements of the device and provides a uniform handling surface, suitable for automated handling of the device.

<u>Device Contact Construction</u>:

A conductive connector will be applied to the element contacts during device manufacture. The various types of conductive connectors have been previously discussed. Electrical contact between the elements and the contacts can be achieved through the use of either conductive adhesives, soldering or mechanical attachment.

The thermistor devices, according to this invention, have the following features: standard SMT package sizes, protective shell which allows automated pick and place without device damage, low cost, tight tolerance and availability in resistance values and with resistance-temperature response characteristics similar to conventional wafer-style thermistor temperature sensors.

A method of making the surface mounted thermistor device may be comprised of the steps of:

a) forming a patterned conductive coating on an insulating carrier substrate such that external and internal electrical contacts are formed;

b) providing electrical continuity between the internal and external electrical contacts;

c) mounting a thermistor element on an internal electrical contact;

d) providing internal electrical continuity between the thermistor element and the carrier substrate by attaching a conductive wire, tape or coating;

e) optionally trimming the resistance values of the element; and

f) forming an encapsulation over the thermistor element of the device.

The present invention may of course be carried out in other specific ways other than those herein set forth without departing from the spirit and essential characteristics of the invention. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive and all changes coming within the meaning and the equivalency range of the appended claims are intended to be embraced therein.

Having thus described our invention with the detail and particularity required by the Patent Laws, what is desired protected by Letters Patent is set forth in the following claims.

WE CLAIM:

1. A surface mounted thermistor device comprising:

a) a thermistor element having a top face with a top conductive coating thereupon and a bottom face with a bottom conductive coating thereupon;

b) a carrier substrate made of an electrically insulating material and suitable for mounting upon a printed circuit board, wherein;

i) the substrate has a bottom face with a first external contact and a second external contact,

ii) the first external contact is in electrical communication with the bottom conductive coating of the element and

iii) the second external contact is in electrical communication with the top conductive coating of the element.

2. The device according to claim 1 wherein the second external contact is in electrical communication with the top conductive coating of the element through a conductive connector.

3. The device according to claim 2 wherein the conductive connector is comprised of one from the group consisting of a conductive wire, conductive tape, conductive epoxy, conductive shunt and a conductive coating.

4. The device according to claim 1 wherein the top face of the substrate has a first internal contact electrically connected to the bottom conductive coating of the element using one from the group of an conductive adhesive, solder or a mechanical attachment and furthermore electrically connected to the first external contact.

5. The device according to claim 4 wherein the top face of the substrate has a second internal contact electrically connected to the conductive connector using one from the group of an conductive adhesive, solder or a mechanical attachment and furthermore electrically connected to the second external contact.

6. The device according to claim 5 wherein the conductive shunt is comprised of a wire electrically connecting the top conductive coating to a ball of high temperature solder which is electrically connected to the second internal contact.

7. The device according to claim 5 wherein

a) the first internal contact and the first external contact are electrically connected by a first intermediate segment extending around the substrate thereby forming a continuous conductive band from the first internal contact to the first external contact and

b) the second internal contact and the second external contact are electrically connected by a second intermediate segment extending around the substrate thereby forming a continuous conductive band from the second internal contact to the second external contact.

8. The device according to claim 7 wherein the continuous bands are formed by a conductive wrap around film.

9. The device according to claim 5 wherein each first and second internal contacts are electrically connected to the corresponding first and second external contacts by conductive material extending through holes in the substrate between the contacts.

10. The device according to claim 1 further including an encapsulation over the thermistor element to

provide a uniform handling surface and to protect the thermistor element.

11. The device according to claim 10 wherein the encapsulation is made of plastic.

12. The device according to claim 1 wherein the substrate is comprised of one non-conducting material from the group of materials of alumina, PCB, fiberglass reinforced epoxy, fiberglass reinforced polyester, ceramic, polyimide film and glass.

13. The device according to claim 1 wherein the conductive connector is insulated from the thermistor element by an epoxy dam placed between the connector and the element.

14. A method of making a surface mounted thermistor device comprising the steps of:

a) forming a patterned conductive coating on an insulating carrier substrate such that external and internal electrical contacts are formed;

b) providing electrical continuity between the internal and external electrical contacts;

c) mounting a thermistor element on an internal electrical contact;

d) providing internal electrical continuity between the thermistor element and the carrier substrate by attaching a conductive wire, tape or coating;

e) optionally trimming the resistance values of the device; and

f) forming an encapsulation over the active thermistor element of the device.

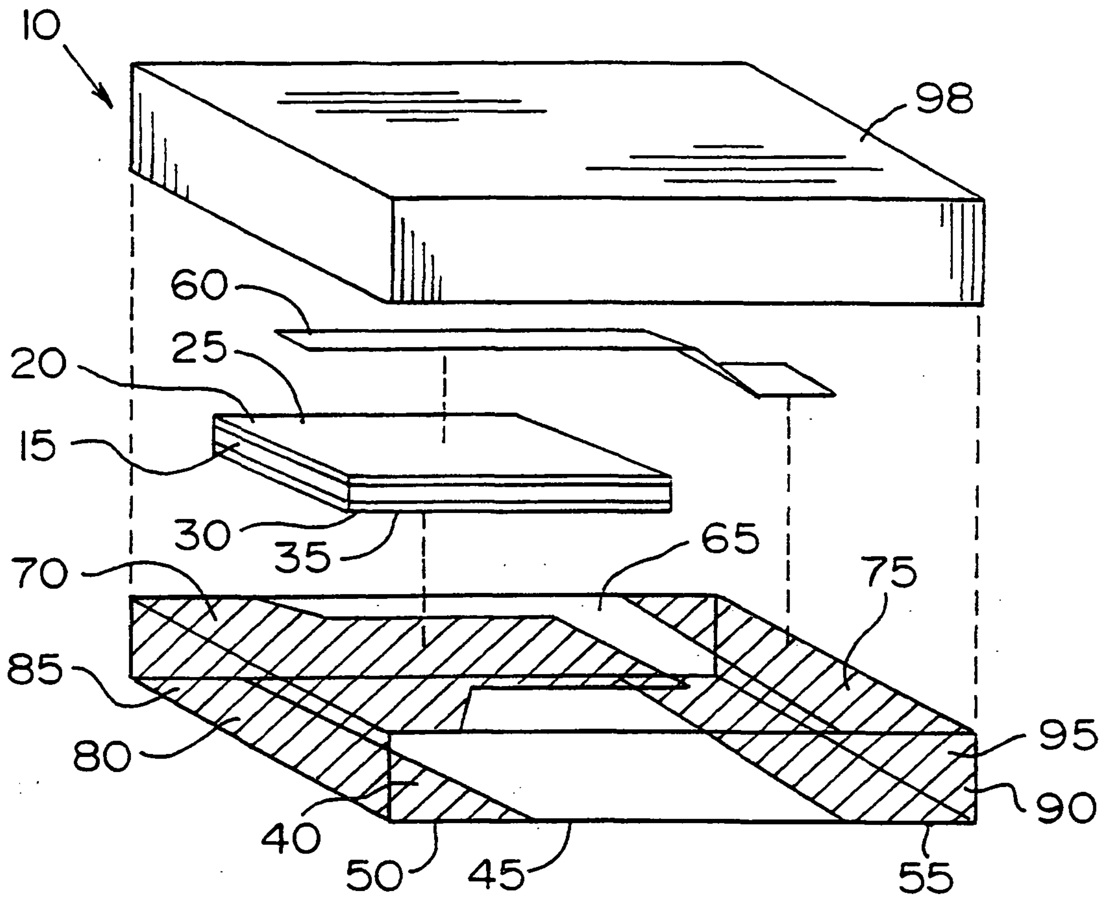
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FIG. 1

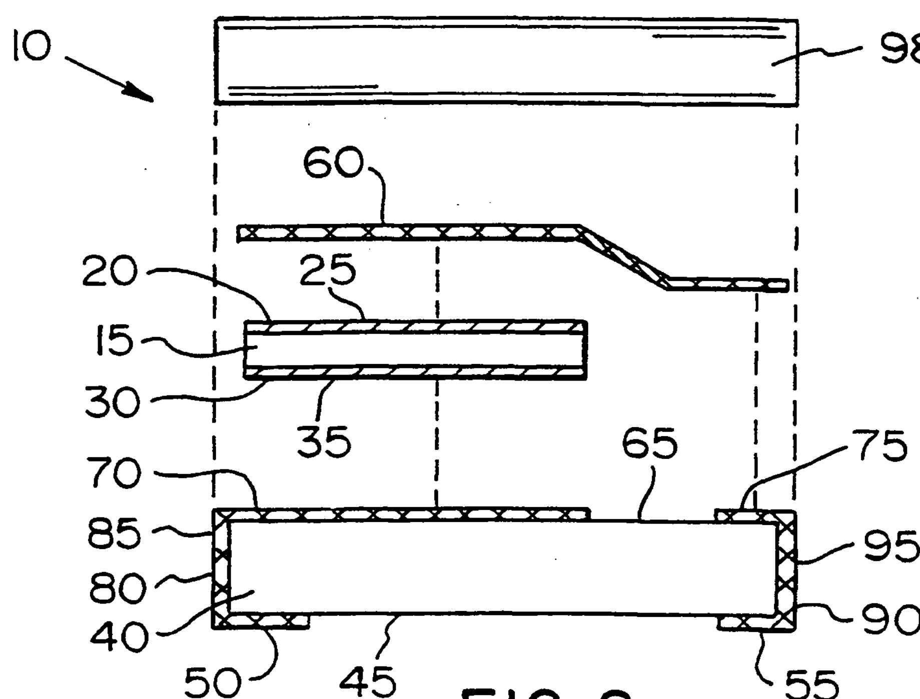
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FIG. 2

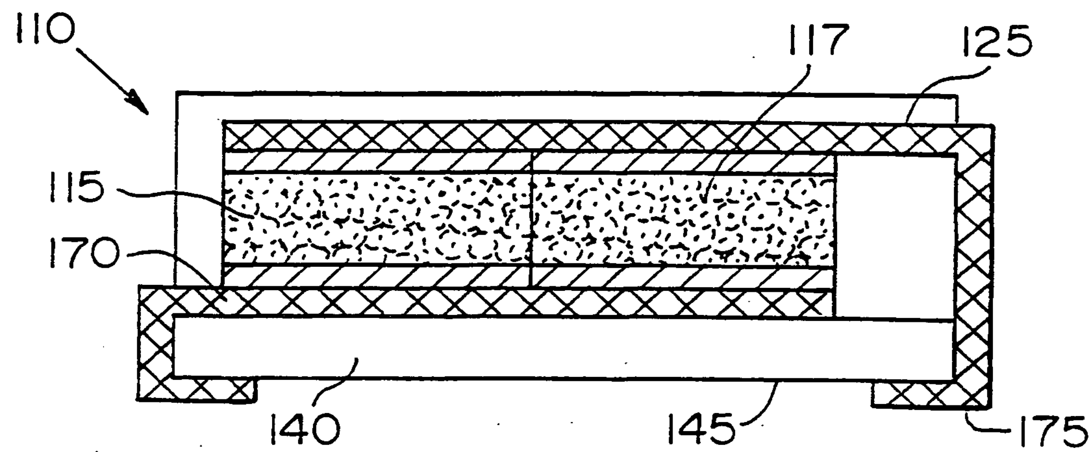

FIG. 3

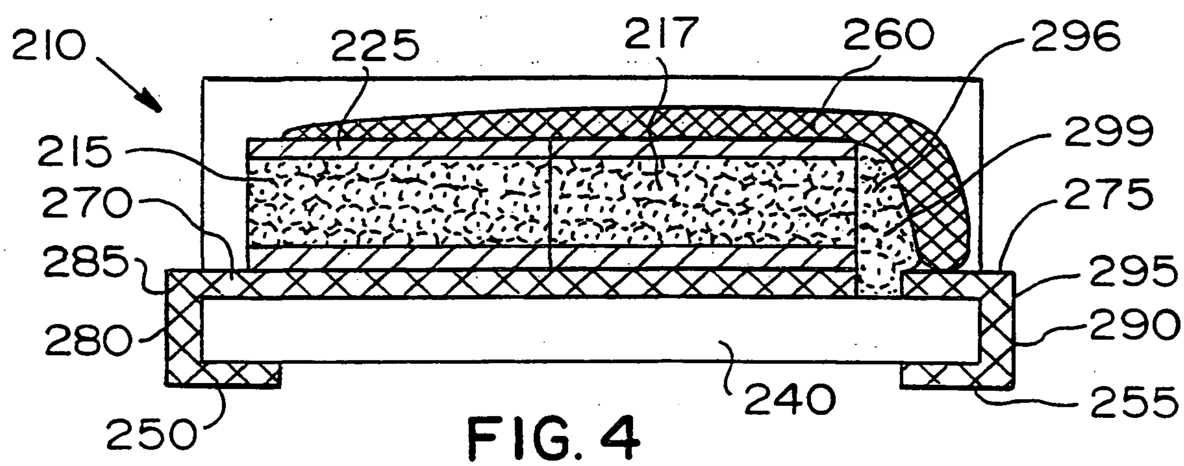

FIG. 4

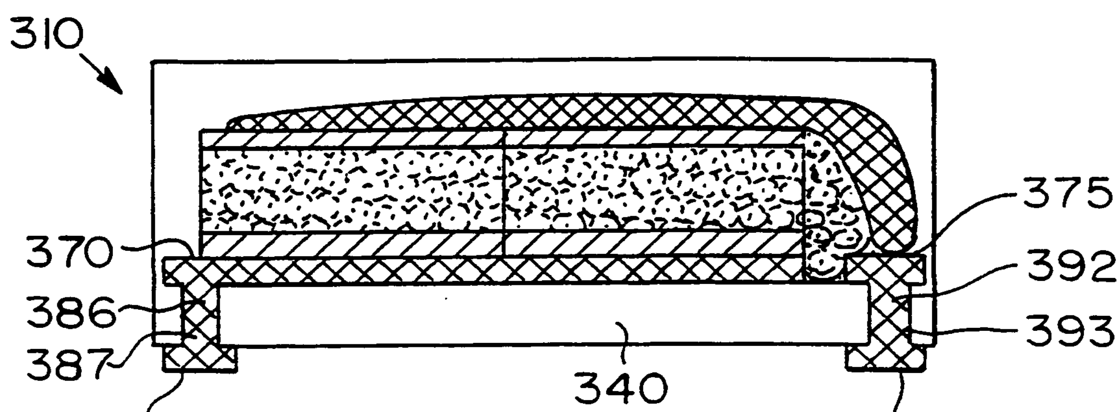

FIG. 5

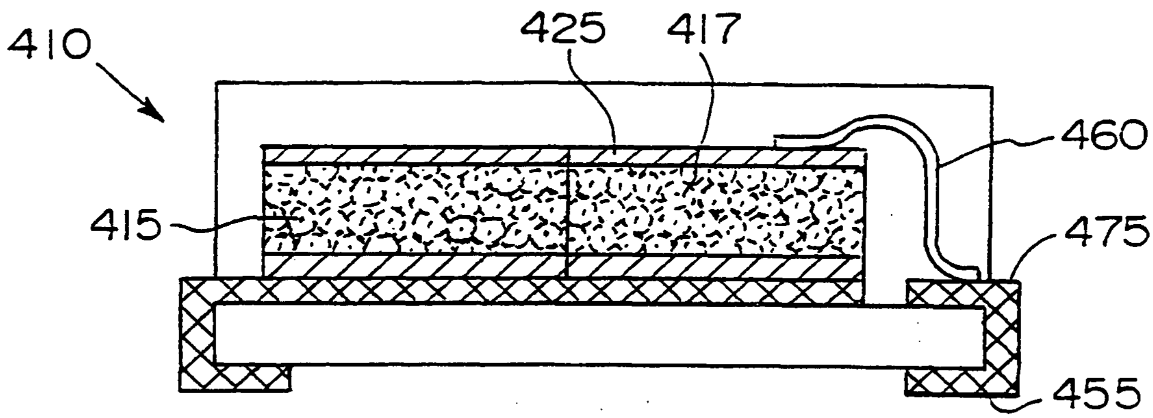

FIG. 6

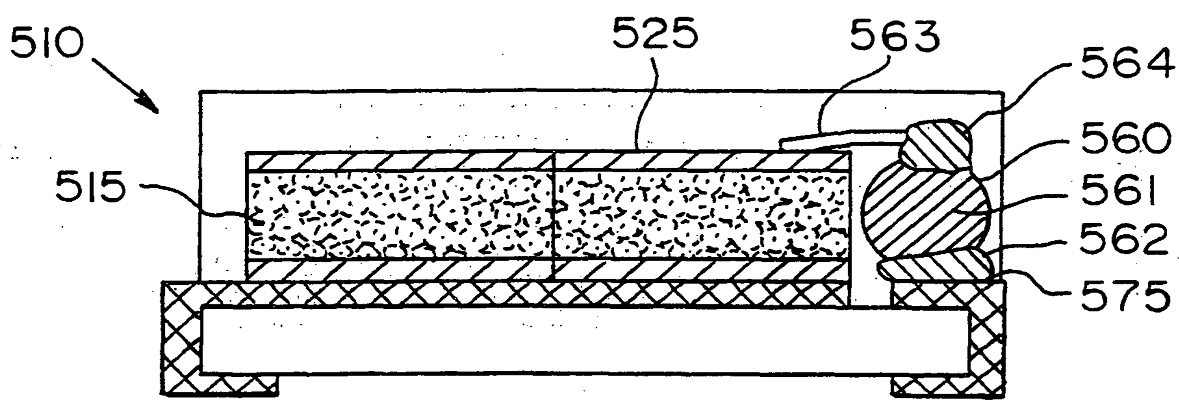

FIG. 7

INTERNATIONAL SEARCH REPORT	International application No. PCT/US99/16074

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :Please See Extra Sheet.
US CL :338/13, 20, 22r, 22sd, 312, 313; 29/610.1, 612, 613, 619, 621
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 338/13, 20, 22r, 22sd, 312, 313; 29/610.1, 612, 613, 619, 621

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,959,505 A (OTT) 25 September 1990 (25-09-90), Figs. 1-3, col. 1, lines 5-60.	1-5, 7, 10-14
X, ---- Y	US 5,056,929 A (WATANABE et al.) 15 October 1991 (15-10-91), Figs. 6-7, 9-11.	1-5, 8-9 ----------- 6
Y	US 5,141,334 A (CASTLES) 25 August 1992 (25-08-92), col. 3, lines 58-61, Fig. 2.	6
A,P	US 5,929,743 A (MIYAZAKI et al) 27 July 1999 (27-07-99), See entire document.	1-14

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/16074

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A, P	US 5,900,800 A (MCGUIRE et al) 04 May 1999 (04-05-99), see entire document.	1-14
A,P	US 5,884,391 A (MCGUIRE et al) 23 March 1999 (23-03-99), see entire document.	1-14
X, P	US A 5,887,338 A (WILDGEN) 30 March 1999 (30-03-99), Fig. 2.	1-5, 10-13
A	US 4,349,958 A (HAKANSSON et al) 21 September 1982 (21-09-82), see entire document.	1-14
A	US 3,976,854 A (ISHIKAWA et al), 24 August 1976 (24-08-76), see entire document.	1-14

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER:
IPC (6):

HO1C 7/10